PATENT COOPERATION TREATY

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INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference F18522 AS/vd	FOR FURTHER ACTION	See Form PCT/IPEA/416
International application No. PCT/IB2004/003838	International filing date *(day/month/year)* 24.11.2004	Priority date *(day/month/year)* 26.11.2003
International Patent Classification (IPC) or national classification and IPC B22D17/22, B22D21/00		
Applicant RAFFLE, Marie Thomas Gilles		

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 4 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. ☒ *sent to the applicant and to the International Bureau)* a total of 15 sheets, as follows:
      ☒ sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      ☐ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.
   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing and/or tables related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).

4. This report contains indications relating to the following items:

☒	Box No. I	Basis of the opinion
☐	Box No. II	Priority
☐	Box No. III	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
☐	Box No. IV	Lack of unity of invention
☒	Box No. V	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
☐	Box No. VI	Certain documents cited
☐	Box No. VII	Certain defects in the international application
☐	Box No. VIII	Certain observations on the international application

Date of submission of the demand	Date of completion of this report
23.06.2005	10.03.2006
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized Officer Bergman, L Telephone No. +49 89 2399-8443

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/IB2004/003838

Box No. I Basis of the report

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

   ☐ This report is based on translations from the original language into the following language , which is the language of a translation furnished for the purposes of:
   - ☐ international search (under Rules 12.3 and 23.1(b))
   - ☐ publication of the international application (under Rule 12.4)
   - ☐ international preliminary examination (under Rules 55.2 and/or 55.3)

2. With regard to the **elements*** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

Description, Pages	
9-18, 20, 21	as originally filed
1-8, 19	received on 25.07.2005 with letter of 21.07.2005
Claims, Numbers	
1-19	received on 25.07.2005 with letter of 21.07.2005
Drawings, Sheets	
1/6-6/6	as originally filed

   ☐ a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing

3. ☐ The amendments have resulted in the cancellation of:
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

* *If item 4 applies, some or all of these sheets may be marked "superseded."*

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-19
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-19
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-19
	No:	Claims	

2. Citations and explanations (Rule 70.7):

see separate sheet

1. Prior art

D1: DE 37 26 217 A (VAILLANT JOH GMBH & CO) 25 February 1988 (1988-02-25)
D2: US-B1-6 250 365 (GALLO SERGIO ET AL) 26 June 2001 (2001-06-26)
D3: DE 41 20 357 A (TEVES GMBH ALFRED) 24 December 1992 (1992-12-24)
D4: PATENT ABSTRACTS OF JAPAN vol. 2000, no. 11, 3 January 2001 (2001-01-03) & JP 2000 218356 A

2. Disclosure of the prior art

D1 discloses preheating of pressure die casting moulds by using induction heating to heat mould to just below working temp by induction heating with an induction coil surrounding the mould, cf abstract, Fig. 1.

D2 disclose a die casting apparatus comprises a die with upper (30) and lower (32) sections, means for maintaining a temperature differential between the die sections, and a means for introducing a molten or semimolten metal under pressure into the mold cavity (26) via the riser and the gate. The sections (30, 32) are separated by a layer of insulating material and define a cavity spanning the layer wherein the lower portion (32) of the mold further comprises induction heaters (34).

D3 and D4 discloses a method of pre-heating of a die casting mould by inserting an induction coil in the opened mould .

3. Novelty and Inventive step

None of the cited documents discloses a method or apparatus for deliberately creating a temperature profile within the mould cavity. In particular, induction heating of the mould in combination with a one-shot induction melting apparatus is not known in the prior art. In the prior art there is not found any hint towards said combination which plausibly leads to improved flexibility of the die casting. Accordingly, an inventive step is acknowledged.

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CASTING OF METAL ARTEFACTS

THIS INVENTION relates to the casting of a metal artefact. More particularly, the invention relates to a process for casting a metal artefact, to a casting assembly for casting metal artefacts, and to a casting apparatus or installation for casting a metal artefact, all being particularly suitable for casting light metal artefacts. As used herein, the term light metal encompasses both light metals as such, and alloys thereof in which one or more light metals form the major proportion of over 50% by mass, light metals being those having a density of less than 2.7g/cm^3. Light metals usually have low melting points of 660°C or less.

According to a first aspect of the invention, there is provided a process for casting a metal artefact by charging a die or mould with molten metal and causing or allowing the metal to solidify in the die or mould to form the artefact, the process including the step, prior to charging the die or mould with the molten metal, of heating the die or mould by induction heating to an elevated temperature, the charging taking place with the die or mould at the elevated temperature,

the induction heating being employed to provide the surface of the interior of the die or mould with a desired temperature profile whereby the interior surface of the die or mould has different parts or zones at different temperatures from each other or one another, in contact with the molten metal charged into the die or mould, thereby

to promote desired cooling and solidification rates in different parts of the metal charged into the die or mould; and

the charging of the die or mould being from a melting apparatus having a capacity to produce a full charge of molten metal which is matched in volume with the capacity or volume of the die or mould, the charging of the die or mould being with sufficient molten metal to produce a single artefact and the charging acting entirely to consume a full molten charge produced by the melting apparatus, the heating arrangement of the melting apparatus being an induction heating arrangement comprising at least one induction coil.

The process may include the step of purging the die or mould, prior to the heating, so that casting of the artefact takes place under a desired atmosphere. Instead or in addition, the purging may be carried out during the heating of the die or mould. Thus, in other words, the process may include the step, prior to the charging of the die or mould, of purging the die or mould with a purging gas, the charging taking place under an atmosphere provided by the purging gas. Preferably, the purging is carried out both prior to and during the heating of the die or mould, the purging being discontinued before the charging takes place. The purging gas may be selected from the group consisting of argon, carbon dioxide and mixtures thereof. Instead said purging may be by means of a gas, such as sulphur hexafluoride (SF_6), which can act as a flux.

The process may include the step, prior to charging the die or mould with molten metal, of sealing off or locking the die or mould. In addition thereto, the process may include the step of disconnecting the supply of purging gas to the die or

mould, prior to charging the die or mould with the molten metal. Typically, the supply of purging gas is discontinued when the die or mould attains its operating temperature. Charging the die or mould will typically be carried out to fill the die or mould to its full capacity.

The charging may be carried out under pressure, acting to fill the die or mould to its full capacity. In particular, and preferably, the filling of the die or mould with the molten charge is under an intermediate pressure, being neither what is known in the art as low pressure injection moulding nor what is known in the art as high pressure injection moulding. More particularly, the charging may be carried out by injection moulding, at an intermediate pressure in the range 50KPa - 30MPa. It will be appreciated that routine experimentation can be employed to determine a desired or an optimum intermediate pressure under which the die or mould should be filled with the molten charge.

The process may include using, as the metal, a metal selected from the group consisting of aluminium, magnesium, lithium, zinc and alloys thereof. Preferably the process includes using, as the metal, a light metal selected from the group consisting of magnesium, aluminium and alloys thereof.

The process is expected to be useful, in particular, in the casting of light metal or alloy products selected from the group consisting of wheel rims, such as aluminium- or magnesium-alloy wheel rims, automotive gearbox casings, steering wheels, steering column housings, brake auxiliary parts or components, and automotive engine, marine and aircraft parts or components. Typically, the process

will be used in the casting of aluminium- and magnesium-alloy wheel rims. Thus, the casting may be of a light metal artefact in the form of a motor vehicle wheel rim.

In particular, the process is expected to be useful in casting artefacts having cross-sectional thicknesses in the range 1.5 – 30mm, usually 2 – 27mm, with respective masses of 0.25 - 30kg, usually 0.5 – 20kg. In other words and more particularly, the casting may be of a metal artefact in which the part of the solidified artefact which is furthest from the surface of the artefact is spaced from the closest part of the surface of the artefact by a spacing of 0.75 – 15mm, the artefact having a mass of 0.25 – 30 kg.

Importantly, the process may include the step of providing the die or mould with a desired temperature profile, by selective application of the induction heating thereto, to promote solidification at desired rates of different parts of the molten light metal charged into the die or mould.

Furthermore, charging the die or mould may be from a melting apparatus which is reciprocably movable relative to the die or mould, the process including reciprocably moving the melting apparatus between a charging position where it is charged with a precursor of the molten charge, and a filling position where the molten charge is transferred from the melting apparatus to the casting assembly. The casting may be carried out in a plurality of dies or moulds each associated with a single melting apparatus from which it is charged, each melting apparatus being associated with a single die or mould and being electrically heated by induction heating, a common electrical power supply being used to supply electrical power to

the dies or moulds for the induction heating thereof, and a common electrical power supply being used to supply electrical power to the melting apparatuses. The process may be carried out by using a casting apparatus or installation as defined hereunder.

According to another aspect of the invention, there is provided a casting apparatus or installation for casting metal artefacts, the apparatus or installation including a casting assembly for casting a metal artefact, the casting assembly including a die or mould for casting the artefact and including also an induction heating arrangement, the induction heating arrangement including at least one induction coil surrounding the die or mould, for heating the die or mould to an elevated temperature prior to the casting of the artefact,

the induction heating arrangement including a plurality of at least two said induction coils which are operable independently of each other or one another to heat the die or mould to said elevated temperature while providing the surface of the interior of the die or mould with a desired temperature profile; and

the casting apparatus or installation including a melting apparatus for forming a molten charge of metal for use in the casting of said metal artefact in the casting assembly, the melting apparatus including a heating arrangement for heating a precursor of the molten charge to a temperature at which the molten charge is formed from the precursor, the melting apparatus having a capacity to produce a full charge of molten metal having a volume which is matched with the capacity or volume of the die or mould so that the casting of a single artefact in the die or mould entirely consumes a full molten charge produced by the melting apparatus when the melting apparatus is operated at full capacity, the heating arrangement of the melting

apparatus being an induction heating arrangement comprising at least one induction coil.

The induction heating arrangement of the casting assembly may be in the form of a variable- frequency induction heater.

The assembly may include a purging gas supply connected to the die or mould for supplying a purging gas to the interior of the die or mould.

The die or mould may be a disposable die, for example such as a sand casting die or mould. Instead, the die or mould may comprise a re-usable die or mould. The re-usable die or mould may be a metal die or mould, preferably a steel die or mould. In particular, the die or mould may be a re-usable multi-core segmented metal die or mould.

In the case of a re-usable die or mould, the die or mould may thus be a multi-core or segmented die or mould, comprising two or more cores or segments. In particular, the die or mould may comprise a top core or segment to which the solidified artefact remains removably attached at the end of the casting. The top core or segment may include or be associated with release means for releasing the artefact therefrom. In this case the die or mould will typically also comprise a bottom– or face core, and a ring of side cores associated with pistons, which side cores or segments give the die or mould its segmented character. In particular, the re-usable die or mould may be hydraulically operable, with regard to the pistons of the side cores and with regard to lifting of the top core and casting from the

remaining cores to bring the casting into contact with pins forming the release means. The die or mould will typically have a charging opening for use in filling or charging the die or mould with molten light metal. In one embodiment of the invention, the die or mould has its charging opening provided through its bottom or face core for charging or filling the die or mould from below. In a preferred embodiment, the re-usable die or mould is hydraulically operable and has a bottom- or face core provided with a metal-charging opening for charging the die or mould with molten metal from below.

The induction heating arrangement may include two or more induction coils, operable independently of one another in achieving a desired temperature profile in the die or mould.

The casting assembly may be of permanent construction as part of an installation, being constructed to remain more or less permanently in situ, at a production facility for casting light metal artefacts. Instead, and preferably, the casting assembly is not of permanent construction, being moveable as part of an apparatus from one said production facility to another.

Preferably the melting apparatus is sized to melt charges of metal which are matched in size with the size of the die or mould, so that casting of the artefact in the die or mould consumes an entire charge.

In each case where the die or mould arrangement, on the one hand, and the melting apparatus on the other hand, include one or more induction heating coils, the induction coils may be electrically connected to an electrical power supply therefor.

The melting apparatus may be reciprocably movable relative to the casting assembly between a charging position where charging of the melting apparatus with a precursor of the molten charge takes place, and a filling position where transfer of a molten charge from the melting apparatus or installation to the casting assembly takes place. Thus, the casting apparatus or installation may include rails, the melting apparatus being mounted via wheels on the rails, the wheels being rollable along the rails during reciprocating movement of the melting apparatus relative to the casting assembly.

The casting apparatus or installation may include two or more of the casting assemblies and the same number of the melting apparatuses, the casting assemblies sharing a common heating power supply and the melting apparatuses sharing a common heating power supply, for the casting of artefacts in respective casting cycles which are sufficiently out of phase to permit such sharing. In other words, the casting apparatus or installation may include a plurality of the casting assemblies and the same plurality of the melting apparatuses, each casting assembly being associated with a single said melting apparatus and each melting

The die or mould 12 is then opened by hydraulically disengaging the ring of side core segments 22 from one another with the aid of the pistons 24, and the top core 16 with the solidified wheel rim 100 attached thereto, is lifted, using the controller 72. The wheel rim 100 is then detached or released from the top core 16 by allowing downwardly directed pins forming part of the release means (not shown) to push the wheel rim 100 downwardly during the raising of the top core 16.

The piston arrangement 52 is lowered and then the barrels of the assembly 48 are retracted, releasing the cylinder or sleeve 42 and the solidified portion or sprue (not shown) of the molten charge which formed the secondary seal for the cylinder or sleeve 42. The used cylinder or sleeve 42 is then cleaned and re-positioned back on the transfer assembly 48 in preparation for the casting of a new wheel rim 100. It will be appreciated, however, that a different cylinder or sleeve 42 may instead be used to avoid waste of production time and also to minimise the possibility of cross-contamination.

It is an advantage of the invention that the casting apparatus or installation 70 need not necessarily to be of a permanent construction, being moveable from one production facility to another with ease. Thus the casting apparatus or installation 70 may be inexpensively set up close to an end user of the artefacts to be cast, thereby reducing transportation costs, and the like.

CLAIMS:

1. A process for casting a metal artefact by charging a die or mould with molten metal and causing or allowing the metal to solidify in the die or mould to form the artefact, the process including the step, prior to charging the die or mould with the molten metal, of heating the die or mould by induction heating to an elevated temperature, the charging taking place with the die or mould at the elevated temperature,

the process being characterized in that, in combination,

the induction heating is employed to provide the surface of the interior of the die or mould with a desired temperature profile whereby the interior surface of the die or mould has different parts or zones at different temperatures from each other or one another, in contact with the molten metal charged into the die or mould, thereby to promote desired cooling and solidification rates in different parts of the metal charged into the die or mould; and

the charging of the die or mould is from a melting apparatus having a capacity to produce a full charge of molten metal which is matched in volume with the capacity or volume of the die or mould, the charging of the die or mould being with sufficient molten metal to produce a single artefact and the charging acting entirely to consume a full molten charge produced by the melting apparatus, the heating arrangement of the melting apparatus being an induction heating arrangement comprising at least one induction coil.

2. A process as claimed in Claim 1, characterized in that it includes the step, prior to the charging of the die or mould, of purging the die or mould with a purging gas, the charging taking place under an atmosphere provided by the purging gas.

3. A process as claimed in Claim 2, characterized in that the purging is carried out both prior to and during the heating of the die or mould, the purging being discontinued before the charging takes place.

4. A process as claimed in any one of the preceding claims, characterized in that the charging is carried out under pressure, acting to fill the die or mould to its full capacity.

5. A process as claimed in Claim 4, characterized in that the charging is carried out by injection moulding, at an intermediate pressure in the range 50 KPa -30MPa.

6. A process as claimed in any one of the preceding claims, characterized in that it includes using, as the metal, a metal selected from the group consisting of aluminium, magnesium, lithium, zinc and alloys thereof.

7. A process as claimed in Claim 6, characterized in that it includes using, as the metal, a light metal selected from the group consisting of magnesium, aluminium and alloys thereof.

8. A process as claimed in any Claim 7, characterized in that the casting is of a light metal artefact in the form of a motor vehicle wheel rim.

9. A process as claimed in any one of the preceding claims, characterized in that the casting is of a metal artefact in which the part of the solidified artefact which is furthest from the surface of the artifact is spaced from the closest part of the surface of the artefact by a spacing of 0.75 – 15mm, the artefact having a mass of 0.25 – 30 kg.

10. A process as claimed in any one of the preceding claims, characterized in that the charging of the die or mould is from a melting apparatus which is reciprocably movable relative to the die or mould, the process including reciprocably moving the melting apparatus between a charging position where it is charged with a precursor of the molten charge, and a filling position where the molten charge is transferred from the melting apparatus to the casting assembly.

11. A process as claimed in any one of the preceding claims, characterized in that the casting is carried out in a plurality of dies or moulds, each associated with a single melting apparatus from which it is charged, each melting apparatus being associated with a single die or mould and being electrically heated by induction heating, a common electrical power supply being used to supply electrical power to the dies or moulds for the induction heating thereof, and a common electrical power supply being used to supply electrical power to the melting apparatuses.

12 A casting apparatus or installation for casting metal artefacts, the apparatus or installation including a casting assembly (10) for casting a metal artefact (100), the casting assembly (10) including a die or mould (12) for casting the artefact (100) and

the assembly (10) including an induction heating arrangement (14), the induction heating arrangement including at least one induction coil (25, 26, 27, 28, 29, 30) surrounding the die or mould (12) for heating the die or mould (12) to an elevated temperature prior to the casting of the artefact (100),

the apparatus or installation being characterized in that, in combination,

the induction heating arrangement (14) includes a plurality of at least two said induction coils (25, 26, 27, 28, 29, 30) which are operable independently of each other or one another to heat the die or mould (12) to said elevated temperature while providing the surface of the interior of the die or mould with a desired temperature profile; and

the casting apparatus or installation includes a melting apparatus (40) for forming a molten charge of metal for use in the casting of said metal artefact (100) in the casting assembly (10), the melting apparatus (40) including a heating arrangement (44) for heating a precursor of the molten charge to a temperature at which the molten charge is formed from the precursor, the melting apparatus having a capacity to produce a full charge of molten metal having a volume which is matched with the capacity or volume of the die or mould so that the casting of a single artefact in the die or mould entirely consumes a full molten charge produced by the melting apparatus when the melting apparatus is operated at full capacity, the heating arrangement of the melting apparatus being an induction heating arrangement comprising at least one induction coil (46).

13. An apparatus or installation as claimed in Claim 12, characterized in that the induction heating arrangement (25, 26, 27, 28, 29, 30) of the casting assembly (10) is in the form of a variable-frequency induction heater (14).

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14. An apparatus or installation as claimed in Claim 12 or Claim 13, characterized in that it includes a purging gas supply line (31) connected to the die or mould (12) for supplying a purging gas to the interior of the die or mould (12).

15. An apparatus or installation as claimed in any one of Claims 12 – 14 inclusive, characterized in that the die or mould (12) is a re-usable multi-core (16, 18, 22) segmented metal die or mould (12).

16. An apparatus or installation as claimed in Claim 15, characterized in that the re-usable die or mould (12) is hydraulically operable and has a bottom- or face core (18) provided with a metal-charging opening (20) for charging the die or mould (12) with molten metal from below.

17. An apparatus or installation as claimed in any one of Claims 12 – 16 inclusive, characterized in that the melting apparatus is reciprocably movable relative to the casting assembly between a charging position where charging of the melting apparatus with a precursor of the molten charge takes place, and a filling position where transfer of a molten charge from the melting apparatus to the casting assembly takes place.

18. An apparatus or installation as claimed in Claim 17, characterized in that it includes rails (67), the melting apparatus being mounted via wheels (66) on the rails, the wheels being rollable along the rails during reciprocating movement of the melting apparatus relative to the casting assembly.

19. An apparatus or installation as claimed in any one of Claims 12 – 18 inclusive, characterized in that it includes a plurality of the casting assemblies and the same plurality of the melting apparatuses, each casting assembly being associated with a single said melting apparatus and each melting apparatus being associated with a single said casting assembly, the casting assemblies sharing a common electrical heating power supply (94) and the melting apparatuses sharing a common electrical heating power supply (92).

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